Very Converting to ^ Narrow Band

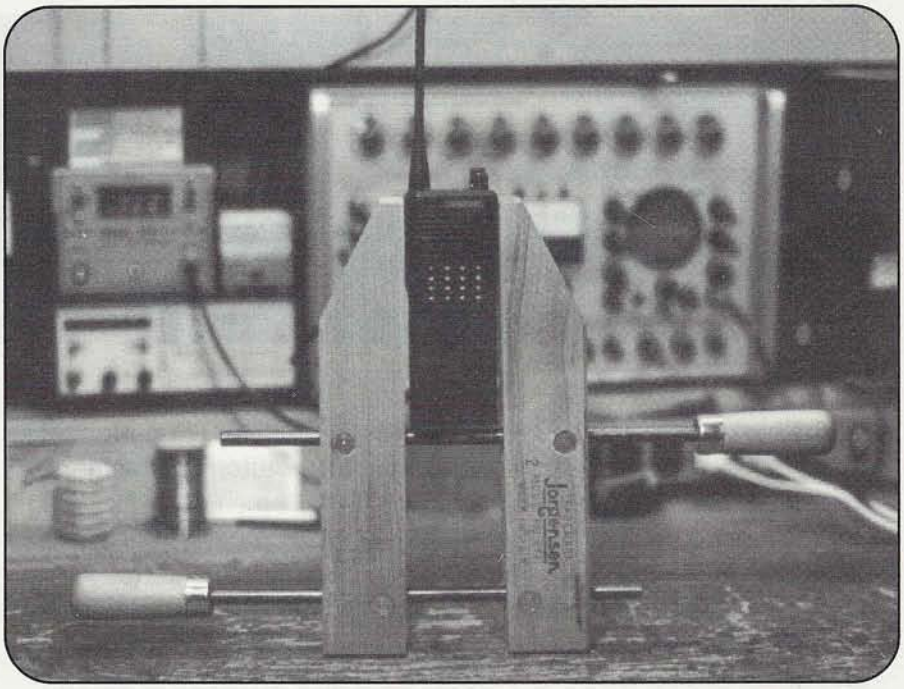
Commercial FM users are squeezing more channels into available UHF spectrum by reducing their bandwidth to 12.5 and even 6.25 kHz. Here's how we can do the same on our 440-MHz band.

By Rod Wheeler, WA6ITC*

Editor's Note: When we printed WA6ITC's "Op-Ed" promoting narrower FM bandwidths in the December, 1996, issue of CQ VHF, *we also challenged him to show us how to do it. He met the challenge. Here's how.*

With more and more amateurs joining our ranks, and it's well over half a million now, we're going to have to use our precious spectrum of frequencies more efficiently.

In reading through the 1984 *Radio Amateur's Handbook* (now *The ARRL Handbook*), I found "The Amateur's Code," right in the front, next to a picture of Hiram Percy Maxim. Point #3 of the code says "The amateur is progressive....He keeps his station abreast of science. It is well-built and efficient. His operating practices are above reproach." On the same page, under Technical Developments, it says that the "ever-growing Amateur Radio continually overcrowds its frequency assignments, spurring amateurs to the development and adoption of new techniques to permit the accommodation of more stations." This need for additional channels on which we can operate will lead to ever narrower channel spacing and bandwidths to more efficiently use our limited radio spectrum.



How do you squeeze more channels into our crowded repeater subbands? You could try this approach, but a narrower IF filter could be much more effective—and less expensive! (Photos by Joel Gelfand, KD6BRI)

We've done a lot to improve this situation on the HF bands, where the use of single sideband transmission has given us a three-fold increase in usable "channels" over the days of AM. For some reason, we haven't done the same in the VHF and UHF spectrum. On 440 MHz, for example, we stopped at 25-kHz channel spacing while the commercial operators went to 12.5-kHz and are now heading for 6.25-kHz spacing.

Maybe it's time to start converting our old 440-MHz FM radios to take advantage of 12.5-kHz channel spacing. The radios will still work fine on the current repeaters but will have sharper IF selectivity. It's like working on the HF bands, but when the bands gets busy, you'd simply switch to narrower filters to help block out adjacent stations.

It's Not Really Difficult

A simple switch of the IF filter in your radio and the implementation of CTCSS encode and decode will open up a lot of new channels for all of us. Old amateur equipment from the '70s and '80s was

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Converting Surplus GE Repeaters to 12.5 kHz

Many amateurs use the General Electric MASTR II, Executive II, and MVP series radios as the building blocks of their repeaters. The 150- and 450-MHz versions of this radio use an 11.2-MHz IF system. Narrow filters at this frequency are difficult to find. But Communication Specialists (see "Resources") has an abundance of 10.7-MHz filters with a bandwidth of 3.75 kHz, so I thought it might be possible to modify the GE radio to a 10.7-MHz IF system.

I replaced the 11.2-MHz filters with the 10.7-MHz narrow filters, realigned the IFs, and it worked! The receiver now had a true 12.5-kHz bandwidth and worked just fine—and all with a few dollars worth of filters. There will be one additional expense: a new receive crystal. Since the IF was changed, I'll have to order crystals .5 MHz higher than I want to listen to in order to end up on the right frequency. Changing the 10.7- or 21.4-MHz IF filters ahead of the 455-kHz filters will improve the overall receiver operation and avoid relying on one filter for all bandpass requirements.

designed for 25 kHz channels because the commercial equipment back then also used 25 kHz separation. Today's amateur FM equipment is a lot better, but it can still be narrowed with little effort and cost. Turning down the transmitter's deviation is even easier, and, if everyone used ± 2.5 kHz, it would allow for a little extra adjacent channel spacing.

I found CTCSS encode and decode capability to be the single greatest help in rejecting adjacent channel interference, with different tones reducing adjacent channel interference by as much as 40 dB. So, by using narrow filters *and* CTCSS encode/decode, we could double, and someday quadruple, our channels on the 440-MHz band. Applying the same concepts to the 2-meter and 222-MHz bands could help solve overcrowding there, too.

Don't Panic!

Now don't panic over the thought changing our current 25-kHz channel spacing to 12.5 kHz on the 440 band. The commercial users did it in the early '80s and found it worked very well. Even changing to 10-kHz spacing on 2 meters and 222 MHz isn't that big of a deal; it's like changing from AM to SSB was on HF. In fact, you don't even need a schematic to modify most FM radios. And, if you do the work yourself, the cost should be about $10. Now that shouldn't wipe out anyone's bank account.

A Bit of Theory, or... Why Bother?

What's the point in changing to a narrower bandwidth if none of the repeaters in your area are doing the same? First, you'll have a tighter receiver that's less prone to interference. Second, you'll be able to use spectrum more efficiently. But how does all this work?

Let's take a look at where selectivity in a receiver is achieved. There are three basic areas of selectivity in the receiver. First is the *front end,* where the input frequency is selected. However, the filter here is usually a bandpass type of filter and the selectivity is designed for a whole band, not a particular frequency. Second is the *Hi IF* Here we find the 10.7 MHz or similar frequency amplifiers and filters. These add greatly to the receiver's selectivity, but only bring it down to the ± 30 kHz range. In some radios (notably the GE MVP and Executive II radios used for many repeaters), you can add filters

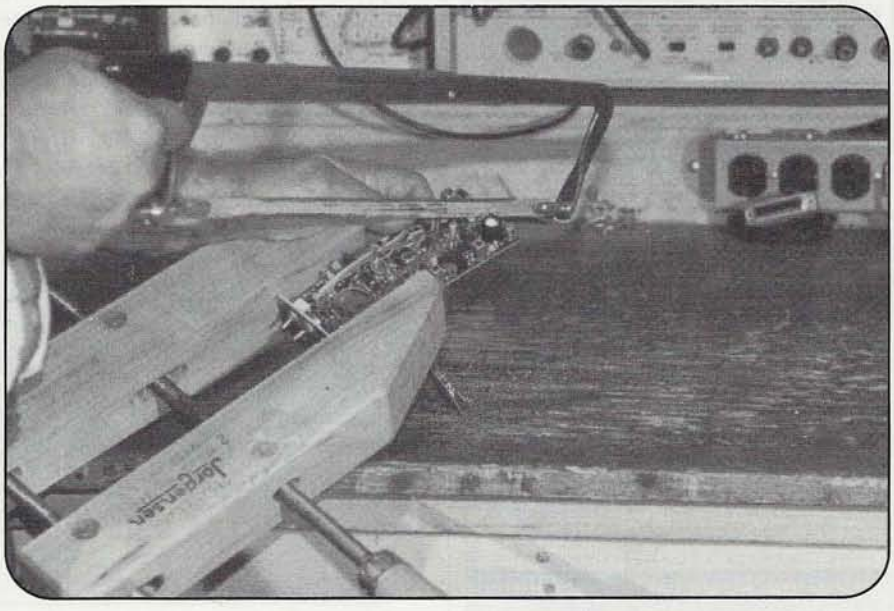
"I found CTCSS encode and decode capability to be the single greatest help in rejecting adjacent channel interference...."

in this area to improve selectivity. Finally, there's the *Low IF,* generally 455 kHz, which is where most radios get their real selectivity, mainly because it's easier and less expensive to do it at 455 kHz than at higher frequencies (see Figure 1).

The Low IF filter is located near the receiver's discriminator or audio detector (sometimes, there's more than one filter, as shown in Figure 1). The vast majority of radios use filters made by muRata. These look like small black cubes with either "455" or "55" written on the top followed by a letter; that letter tells you how selective your radio is (see Figure 2). The filters are very inexpensive and readily available (see "Resources").

Open Up That Case

To sharpen the selectivity of your radio, you'll need to find out which filter you have and which one you need. Take your radio apart and find the receiver board and locate the 455-kHz IF filters (see photo).[1] (Remember the letter after the "455" or "55" tells you the bandwidth



No, this won't narrow your bandwidth, although it WILL significantly reduce your deviation level! Again, a narrower IF filter might be a better option.

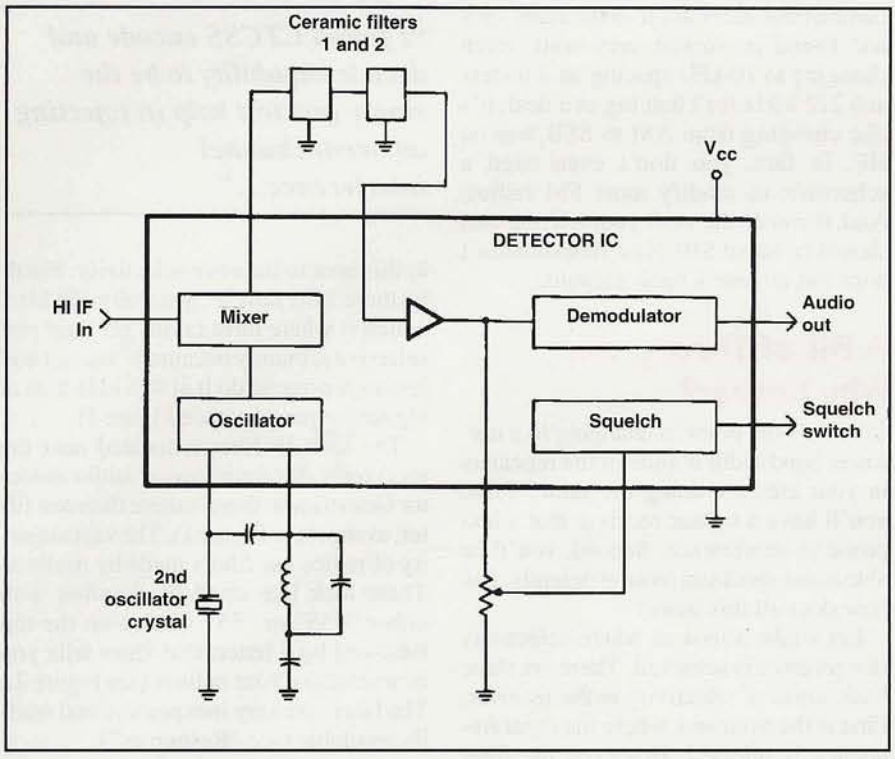


Figure 1. A basic IF detector circuit. Note that some use only one filter; others use more than one, as illustrated above.

"You don't even need a schematic to modify most FM radios. And if you do the work yourself, the cost should be about $10.00."

bandwidth. These filters are too wide for the demands of 12.5-kHz channel spacing and should be changed.

To determine the necessary bandwidth for a given transmitted signal you can use the following formula (assuming a maximum modulation frequency of 3 kHz):

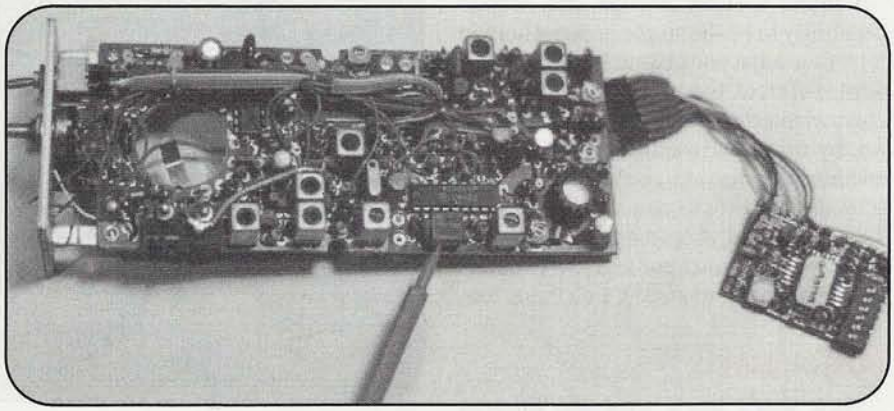
2 (deviation in kHz) x 2.4 = bandwidth in kHz[3]

For instance, with ±5-kHz deviation, you have (2 x 5) x 2.4 = 24-kHz bandwidth. So even though you only deviate ± 5 kHz, your signal takes up more actual spectrum. Your receiver only needs to hear the major portion of the transmitted signal in order to give you readable copy, which is why ±10-kHz IF filters work for ±5-kHz deviation. Now, if you reduce your deviation to ± 2.5 kHz, it changes things to (2 x 2.5) x 2.4 = 12 kHz.

Again, because the receiver doesn't need to "copy" all of the transmitted signal, you can use a ±3.75-kHz IF filter with a 7.5-kHz bandwidth to copy a signal with 2.5 kHz deviation and a 12-kHz bandwidth. Now, if you take two of those 12-kHz-wide signals and put them next to each other, you've got two discrete channels in a space now occupied by one—*doubling* the current number of channels (the roll-off of the filters provides the necessary separation between the channels).

of the filter.) The most commonly used filters are designated A, B, C, D, E, F, and G.[2] Some radios have one filter and some two. There is also a double filter that's about twice as wide. They all do the same thing, though, so you just need to use the chart in Table 1 to determine which filter you have and what you need to get.

I personally use the "G" filters or ±4.5 kHz bandwidth at -6dB. This gives me the best adjacent channel rejection and still maintains the necessary bandwidth for all current repeaters. For instance, most radios have a "D" filter, or ±10-kHz



No joking. This is what the 455-kHz IF filter in a radio typically looks like. You'll need to replace it in order to narrow your bandwidth.

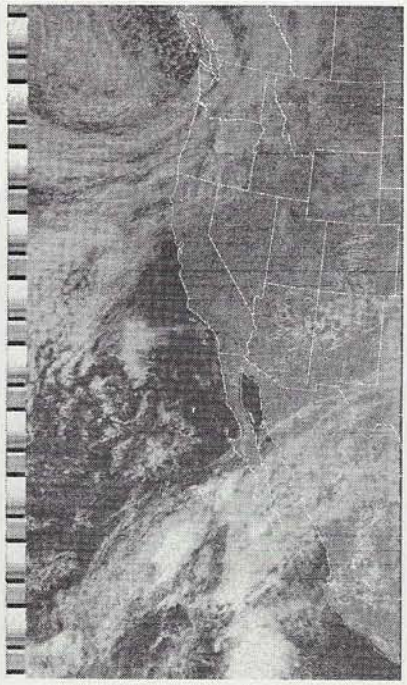
Get The Picture!

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Table. The Basic Filter Bandwidths (at -6 dB)

A= ±17.5 kHz	F= ±6.0 kHz
B= ±15.0 kHz	G= ±4.5 kHz
C= ±12.5 kHz	H= ±3.75 kHz
D= ±10.0 kHz	I= ±2.0 kHz
E= ±7.5 kHz	

I've found that, in practice, a tighter filter than calculated can be used without noticeable deterioration of signal quality. This is probably because most conversations are not at full deviation, and the filters don't have straight slopes on there bandpass. In addition, as noted earlier, using CTCSS encode and decode all the time further eliminates adjacent, and even some co-channel, interference.

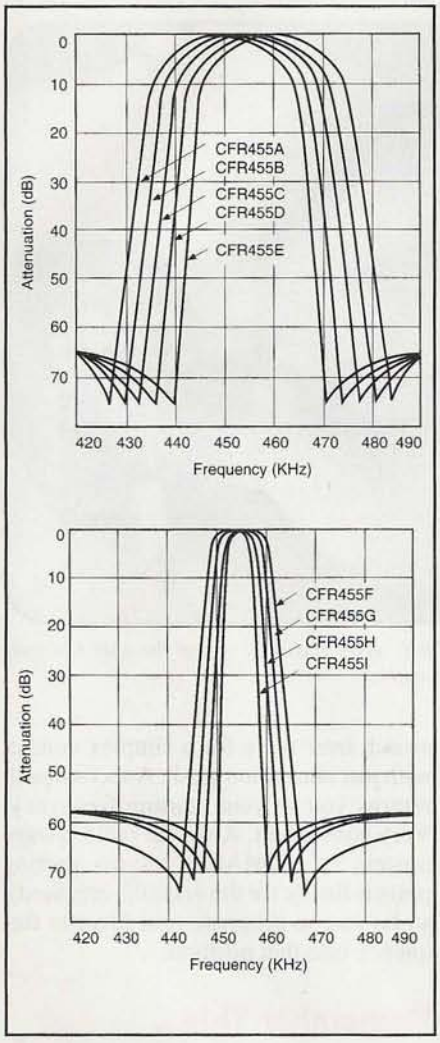

Figure 2. Typical response curves for muRata 455-kHz IF filters. Note the difference between the bandwidth of the filters in Figure 2a (bandwidths A–E; most 70-centimeter ham rigs use "D" filters) and those in Figure 2b (bandwidths F-I; the author recommends going to ±3.75 kHz "H" filters for reduced bandwidth. (Courtesy muRata)

Can You Squeeze It Tighter?

Now, if you want to experiment with *really* narrow operation, you can use the "I" filter at ± 2.0 kHz. Using this filter, you could start approaching the 6.25-kHz channel spacing the commercial operators are trying to attain. If you run 6.25 kHz through the formula, the deviation gets really narrow—1.25 kHz. I believe it's possible to use ± 2kHz at 6.25-kHz channel spacing and still have the radio work fine. One side note: when you reduce the deviation, the recovered audio will be reduced as well. So you'll need to turn up the volume on your receiver.

Done and Done

So that's all there is to it: find the 455-kHz filter and change it. Be careful, and if you're not confident doing the work, find a technician who can do it for you.

We need to continue experimenting to see what else we can work out and improve upon. If we all changed to the narrower filters, we could greatly increase the number of usable FM channels in our VHF and UHF bands—and we could all use that. Don't wait, let's all get on the narrow bandwagon now! ■

Notes

1. If your radio doesn't have a 455-kHz IF (as is the case in some commercial equipment), contact the manufacturer for possible factory modifications for 12.5-kHz operation.

2. Filter data courtesy of muRata.

3. FM and repeaters for the Radio Amateur, *ARRL, 1972.*

Resources

Narrow-bandwidth 455-kHz IF filters are available from:

muRata, 2200 Lake Park Dr., Smyrna, GA 30080: Phone: (770) 436-1300

Communication Specialists has a large inventory of IF filters for certain other frequencies, such as 3.75 kHz, 10.7 MHz, 21.4 MHz, and 21.8 MHz). If you can't find these parts locally, call them directly at (800) 854-0547.

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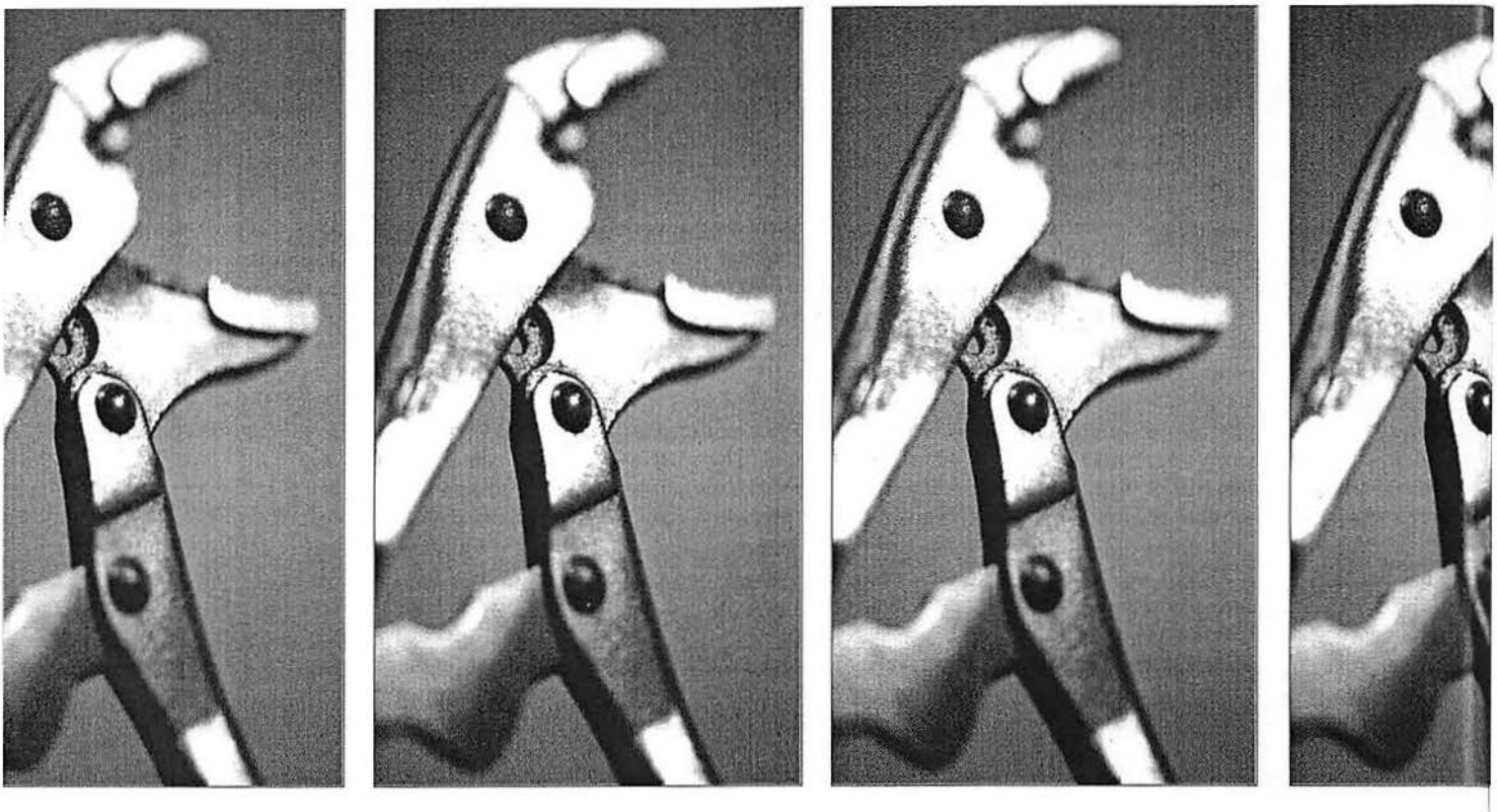

12.5kHz the easy way

Upgrading repeaters designed for 25kHz channel spacing to 12.5kHz channel spacing seemed impossible before. Now, the availability of new filter kits allows modifications to accomplish narrowbanding—without junking your repeater.

By Rod Wheeler

Changes in FCC rules are moving us from the present 25kHz channel spacing at 450MHz to 12.5kHz spacing, and to tighter spacing in the 150MHz band. This change will require more than just reducing the deviation to ±2.5kHz.

Most repeaters in operation today were designed for 25kHz channel spacing. Converting them to the tighter 12.5KHz channel spacing seemed impossible because the manufacturers did not have a modification kit to do the job, and many would like you to buy new equipment anyway. Although the repeaters had the required frequency stability, the lack of narrow IF filters was a major stumbling block.

A few years ago, I wrote an article, "Converting to Very Narrow Band" *(CQ VHF,* July 1997), in which I discussed an experiment conducted on a GE UHF MVP mobile. I wanted to see if it was possible to convert the MVP from 25kHz spacing to 12.5kHz spacing. Checking the GE parts information, I only found a filter change for *20kHz* spacing, far from what I needed for the experiment. Another problem was that the GE Master II series of radios (Mastr II, Executive II, and MVP) are single-conversion receiver designs with an IF frequency of either 11.2MHz or 9.4MHz. There are no 455kHz second IFs to play with where filters are available.

So we tried another angle on the conversion of the GE MVP to 12.5kHz channel spacing. Because the 11.2MHz IF frequency was only 0.5MHz away from the common 10.7MHz IF frequency used in many radios, I decided to try to change the IF frequency to 10.7MHz. This change in the IF frequency would require a change in the injection frequency to reflect the 0.5MHz change in the IF frequency.

Five 10.7MHz crystal filters, designed for 12.5kHz channel spacing, were acquired from Communications Specialists in Orange, CA. The GE MVP was disassembled, and its old filters were replaced with the new 10.7MHz filters. A new receiver crystal was purchased so the injection would be 0.5MHz lower than the original crystal.

The mechanics of replacing the filters is easy, but be careful to keep the crystal pairs together (the crystal filters are shipped in matching pairs). When installing them in the radio, make sure the "dots" on top of the

Wheeler has been involved in with repeaters since 1964. He is the radio shop foreman at Disneyland, Anaheim, CA.

filters face each other. The first filter board in the GE MVP has two filters (four poles) with input and output tuning coils and an adjustable capacitor between them to facilitate alignment. The second IF filter board comes in two versions, one with, and one without, tuning coils; neither has the variable capacitor for finetuning of the filter. Also, most boards have only two filters (four poles), but all of the boards have the holes to mount a third filter, for a total of three crystal filters (six poles) on the second IF board.

After checking the schematic, I installed the third filter (Mastr IIs have the extra filter), and an adjustable capacitor was added to help in tuning the new filter.

After installing the 10.7MHz filters and aligning the receiver, testing showed the receiver to be working just fine. No change in sensitivity could be detected. The squelch and CTCSS decoder worked fine. (And it's good that GE put an audio level pot in the detector circuit to help compensate for the lower deviation.) So, the receiver was working fine at 12.5kHz spacing or ±2.5kHz deviation.

The transmitter was changed in two ways. First, the deviation was turned down to a total of ±2.5kHz—exactly half of the old level. Second, the GE 0.005% crystal was changed to the 0.0025% EC2 type.

This is not really a difficult change, and it's a lot less than a new radio (less than $100), but it could have been easier—and now it is. I found that in trying to convert the current 25kHz spacing to 12.5kHz spacing, the major stumbling block was not the transmit crystal at 0.0025%, which most manufacturers have available, but the IF crystal filters. While in my article I pointed out that Murata makes many 455kHz filters (the "D" ±10kHz [normal for 25kHz spacing], the "E" ±7.5kHz, the "F" ±6kHz, the "G" ±4.5kHz [normal for 12.5kHz], the "H" ±3.75kHz and the "I" ±2.0kHz), *finding* them is not so easy, except for the standard ones used in normal radios.

Manufacturers' charts show the various selective curves of the filters for comparison. However, remember that deviation and bandwidth are not the same; bandwidth equals about 2.4 times the deviation. The problem is where to find the filters; you cannot just order them from Murata, for example, on a one- or two-piece order.

The major stumbling block has been removed, and now it is possible to not only order the 10.7kHz and 12.5kHz filters, but 11.2kHz, 11.7kHz, 21.4kHz and others, along with the 455kHz "E," "F," "G," "H," and "I" filters from Communications Specialists. It is now easy to modify not only the GE Mastr II but also the Motorola Micor and Mitrek, along with many import radios, to the new 12.5kHz channel spacing.

You can get by with only changing the 455kHz filter to get 12.5kHz channel spacing, but why have your receiver process all those adjacent channel signals, when by replacing the high IF filters your receiver has to handle only a single signal?

I can remember converting the old GE Progress Line radios in the 1960s from 50kHz channel spacing to 25kHz spacing.

As soon as the new 11.2kHz–12.5kHz filters became available, three sets were acquired and installed in a GE MVP. Five filters were installed. The second set of two needed a variable capacitor for tuning, but the others were simply installed in the normal circuit. All of the new filters were tuned normally using a ±2.5KHz deviation signal modulated at 1,000Hz. At the conclusion, no difference in sensitivity could be detected. In fact, it might have been a little better. The newer generation of filters may be made better than the old ones—the simplicity of tuning made it easier

Communications Specialists is putting together filter kits with instructions on how to modify many of the radios and repeaters in use today to the new 12.5kHz channel spacing. The cost of these kits is much less than replacing the repeater.

I can remember converting the old GE Progress Line radios in the 1960s from 50kHz channel spacing to 25kHz spacing. We removed the IF coil assembly and physically moved the coils apart and realigned the receiver. Then we added a few parts to the transmitter and reduced the deviation from ±15kHz to ±5kHz. The crystal filter changeout process of today is much easier and can bring many more years of service to our currently operational repeaters and radios.

Getting even narrower

What about 6.25kHz spacing? It can be done. I have an operating repeater on the amateur 440MHz band using ±1.25kHz deviation. The repeater uses two Kenwood TK810 mobiles (one for TX one for RX) modified with 0.0025% TCXOs, eight-pole 12.5kHz IF filters (6.25kHz is not yet available) and an "I" ±2kHz 455MHz second IF filter. Kenwood TK810s are also used for the mobiles. The experiment is working well, and we are learning a lot.

You do not need that entire spectrum just to talk. ■

Acknowledgements

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